*Journal of Crop and Weed, **9**(1):89-93(2013)*

Effect of integrated nutrient management on available phosphorus influencing grain and straw yield of rice (*cv. IR-36*) in an Alfisol

LUNGMUANA, M. GHOSH AND P. K. PATRA

Department of Agricultural Chemistry and Soil Science
Bidhan Chandra KrishiViswavidhyalaya
Mohanpur -741252, Nadia, West Bengal

Received: 02-2-2013, Revised: 25-4-2013, Accepted: 30-4-2013

ABSTRACT

*A field experiment was conducted during 2007 kharif season in a farmer's field in the Red and Laterite zone of West Bengal to evaluate the effect of integrated use of fertilizer with organic amendments viz., rice straw, glyricidia leaves, farm yard manure and vermicompost, on transformation of phosphorus in the rice rhizosphere soil in relation to growth and yield of rice (cv. IR-36). Rhizosphere soil and plant samples collected from rice field during tillering, flowering and harvesting stages of rice were analyzed. Chemical fertilizers and vermicompost furnished the highest amount of available phosphorus in the rhizosphere and produced the highest rice grain yield.These parameters were found to be significantly and positively correlated. Simple regression analyses revealed that about 90% (R^2=0.90**) of the variability in grain yield could be explained by the variability in available phosphorus.This experiment clearly brought out the beneficial role of organic amendment on the availability of phosphorus to rice crop particularly at the later stage of growth.*

Keywords: Alfisol, available P, grain yield

Phosphorus (P) deficiency is a major constraint to agricultural production affecting an area of over 2 billion hectares worldwide (Fairhust *et al.,* 1999). Plant availability of inorganic P in acid Alfisols in the tropics can be limited by its adsorption onto Fe and Al oxides and by formation of Fe and Al phosphate complexes with humic acids (Gerke, 1992). Phosphorus transformation in soils involves complex microbiological, chemical and biological process. Unlike C and N, phosphorus does not undergo oxidation-reduction reaction in soil but occupies a central position in organic matter decomposition (Zibilske *et al.,* 2002). Plant roots acquire P as inorganic P from the soil solution. Immobilization of inorganic P by microbes and its gradual release via microbial turnover can protect P from physicochemical adsorption reactions if their release is synchronized with the demand of growing plants and or a subsequent generation of microorganisms (Magid *et al., 1996*). A significant part of P, held in soil microorganisms, also is a readily available P source for plants (Macklon *et al.,* 1997). Microbial decomposition of organic matter produces organic acids which either replace P sorbed on metal hydroxides or bring about dissolution of P locked in metal oxides by forming complexes with iron and aluminium (Hue *et al.,* 1986). To improve the efficiency of P application, to sustain crop productivity, restore soil health and also to meet a part of chemical fertilizer requirement, it is imperative to maximize the recycling of P from crop residues and organic and mineral fertilizers (Hegde and Dwivedi, 1993). Integrated use of organic manures and phosphatic fertilizers result in not only improved efficiency of the latter (Vats *et al.,* 2001; Sakhen *et al*., 2011) but also significantly increase the availability of P (Maharajan *et al.,* 1997). In highly weathered tropical soils, P availability may depend more on the turnover of easily decomposable soil organic matter (Nziguheba and BůNemann, 2005), than on desorption reduce the introduction part to 2/3 of inorganic P (Tiessen and Shang, 1998).Decline in crop yields due to continuous and indiscriminate use of high analysis chemical fertilizers has been observed throughout the world. While decline in soil fertility and productivity due to nutritional imbalance has been recognized as one of the most important factor limiting crop yields (Nambier and Abrol, 1989), the decline in organic carbon content of the soil could be arrested and the gap between potential and actual yield could be bridged to a large extent (Tolanur and Badanur, 2003), if chemical fertilizers are applied in conjunction with organic manures.

The present investigation was undertaken to study the effect of integrated use of organic and inorganic amendments on the dynamic changes in available phosphorus content of a *Typic Haplustalf* soil containing inherent low organic carbon and its influence on grain and straw yield of rice.

MATERIALS AND METHODS

A field experiment was conducted during *Kharif* (Rainy) season (July-October), 2007 in a farmer's field at Jhargram located at $22^0 45^/$ N and $86^0 98^/$ E at an elevation of 81 m above mean sea level (MSL) in the sub-humid tropical zone of Eastern India. The soil was typical lateritic soil (Typic Haplustalf) growing rice with good drainage facilities and texturally classified as sandy loam.

Email: drpatrapk@yahoo.co.in

There were four replications of each of the following six treatments *viz.*, T_1- Control, T_2- Straw+NPK, T_3-Glyricidia leaves+NPK, T_4-Farm Yard Manure (FYM)+NPK, T_5-Vermicompost+NPK, T_6-Chemical Fertilizer. The plots of control treatment (T_1) received no organic matter or chemical fertilizers, the plots of fertilizers (T_6) received inorganic fertilizers @ N: P_2O_5 and K_2O in the ratio of 80:40:40 kg ha^{-1} respectively, through urea, single super phosphate and muriate of potash. Plots from T_2 to T_5 received organic carbon @ 1000 kg Carbon per hectare through organic amendments viz., rice straw, farm yard manure (FYM), vermicompost and glyricidia leaves. All the organic amendments were locally procured and applied to the field plots. The nutrient content of all the amendments are presented table- 1. The N, P_2O_5 and K_2O contents of the applied organic sources were computed and required balance amount of N, P_2O_5 and K_2O were compensated through inorganic fertilizers. In all the field plots except the control (T_1) treatment, N, P_2O_5 and K_2O were applied in the ratio of 80:40:40 kg ha^{-1} through inorganic fertilizers (as in T_6) or combination of organic manures and inorganic fertilizers (as in T_3, T_4 and T_5). Rice variety IR – 36 was grown to maturity following standard cultural practices. Soil and plant samples were collected from the plot at the time of maximum tillering (30 DAT), booting or flowering (60 DAT) and harvesting stages (90 DAT) by following standard technique (Katznelson *et al.*, 1948).

Table1: Nutrient content of organic amendments (on air dry basis)

Amendments	Total C (%)	Total N (%)	Total P_2O_5 (%)	Total K_2O (%)
Rice straw (Stored)	50.46	0.42	0.07	1.48
FYM	15.37	0.57	0.19	0.48
Vermi compost	16.59	1.14	1.33	1.40
Glyricidia leaves	54.52	2.76	0.28	0.46

The collected surface soil samples were air dried, ground, passed through a 2 mm sieve and stored temporarily in polyethylene bags. The experimental soil was a sandy loam having sand - 77.12%, silt- 6.0% and clay-16.88% (Bouyoucous, 1962) with acidic reaction (pH- 4.64) (Jackson, 1973); low CEC (Schollenberger and Simon,1945) [9.40 c mol (p+) kg^{-1}]; low organic carbon content (0.49 %) (Walkley and Black, 1934); low total nitrogen (0.026 %) (Jackson,1973); low available potassium (ammonium acetate extractable) (50.02 $mgkg^{-1}$) (Jackson, 1973) and low available P (8.48 mg kg^{-1}) (Bray and Kurtz, 1945). The phosphorus content of plant samples was determined by tri-acid digestion method (Jackson, 1973). The data generated were analyzed following standard statistical methods meant for randomized complete block design (Gomez and Gomez, 1984). Duncan's multiple range test (DMRT) at 5% was followed to compare the treatment means. Pearson's correlation coefficients of rice grain and straw yields with available P content of soil and total P content of rice plants at different growth stages and regression co-efficient of grain yield with available phosphorus content of the rhizosphere during different stages of rice growth were also calculated.

RESULTS AND DISCUSSION

Available phosphorus

The changes in the available phosphorus content of the rhizosphere soil under different amendments during the three rice growth periods are presented in table-2. In all the plots substantial increase in available P from initial value of 8.48 mg kg^{-1} soil was observed. While the chemical fertilizer treated (T_6) plots started showing a decreasing trend after the initial increase (up to tillering stage), in all other treatments (including the control), this increase in available P content of rhizosphere soil continued up to the flowering stage and then started decreasing.

Table 2: Effect of amendments on the available phosphorus content of rhizosphere soil

Treatments	Available P (mg kg^{-1}) Growth period			
	Tillering	Flowering	Maturity	Mean
Control	9.5^{e}	10.0^{c}	8.7^{c}	$\mathbf{9.4^{C}}$
Rice straw	14.4^{c}	14.3^{b}	13.1^{b}	$\mathbf{13.9^{B}}$
Glyricidia	12.1^{d}	14.7^{b}	13.4^{b}	$\mathbf{13.4^{B}}$
FYM	15.4^{b}	16.0^{a}	15.7^{a}	$\mathbf{15.7^{A}}$
Vermi compost	14.8^{c}	15.4^{ab}	16.4^{a}	$\mathbf{15.5^{A}}$
Chemical fertilizer	16.6^{a}	15.6^{ab}	15.4^{a}	$\mathbf{15.9^{A}}$
Mean	$\mathbf{13.8^{Q}}$	$\mathbf{14.3^{P}}$	$\mathbf{13.8^{Q}}$	
SEm (±)	**0.24**	**0.34**	**0.37**	
LSD(0.05)	**0.71**	**1.03**	**1.10**	

*Note: *In a column values with similar alphabet are not significantly different through DMRT (P=0.05)*

Similar results were observed by many other researchers (Singh *et al.*, 2006; Tirol-Padre *et al.*, 2007). All the experimental plots, whether treated with organic residues (T_2, T_3) or organic manures (T_4, T_5) or with chemical fertilizer (T_6), maintained higher level of available P as compared to the control (T_1) plots. The available P content of the chemical fertilizer amended plots (T_6) was the highest. The chemical fertilizer treated plot (T_6) showed periodic decline in their available P contents as the crop grew to maturity. Since these plots did not receive any organic amendment the soluble P from chemical fertilizers, was exposed to P-fixation reactions in soil. Phosphate fixation in sesquioxide rich tropical soil (like lateritic soil) had been a matter of investigation by many researchers and a large volume of available literature confirm this phenomenon (Bohn *et al.*, 1979; Sanyal and De Datta, 1991).

The initial increase in available P content of the rhizosphere soil could be due to applied chemical fertilizers, priming effect of applied inorganic P, mineralization of organic phosphorus in the organic manure as well as native soil organic phosphorus (Subehia *et al.,* 2005; Laxminarayan and Patiram, 2006), increasing labile P of the soil by complexing Ca, Mg and Al and decrease in P adsorption due to application of organic manure and/or inorganic P fertilizer (Subehia *et al.,* 2005; Varalaxshmi *et al.,* 2005).The decrease in the available P in the rhizosphere soil beyond flowering stage was due to transformation of available P into unavailable P pool due to resorption by clay minerals and hydrous oxide of Fe in the anaerobic zone, precipitation after diffusing into the oxidised zone or microbial degradation of organic anions at the exchange sites causing P resorption from soil solution (Ponnamperuma, 1972; 1985; Patrick *et al.,* 1985) and also plant uptake. The undecomposed organic residues (T_2, T_3) though proved to be better than control (T_1), they were less effective in furnishing available P in the rhizosphere than decomposed organic manures (T_4, T_5). The available P content of chemical fertilizer and decomposed organic manure *viz*., FYM, vermicompost (T_4, T_5) treated plots were comparable.

Micro-organisms, which play a key role in organic P transformation through excretion of phosphatase and phytase enzymes, mineralization of P from organic sources, synthesis and release of organic P have contributed to this transformation. Organic acids produced as a result of organic matter decomposition might have replaced P sorbed on metal hydroxides, or brought about dissolution of P locked in metal oxides by forming complexes with iron and aluminium also. During all the rice growth stages, available P content of soil showed significant correlation with grain yield (r=0.85** to 0.94**) and straw yield (r=0.83** to 0.92**) (Table 3).

Table 3: Correlation co-efficient of rice grain and straw yield with available P content of soil and total P content of rice plants at different growth stages

	Available P content in soil			Total P content of rice plant		
	Tillering	**Flowering**	**Harvesting**	**Shoots (Tillering)**	**Shoots (Flowering)**	**Straw (Harvest)**
Grain yield	0.85**	0.90**	0.94**	0.51*	0.23	-0.09
Straw yield	0.83**	0.88**	0.92**	0.53**	0.28	-0.04

*Note: *,** Significant at 5% and 1% level, respectively*

Phosphorus concentration of the rice plant

Phosphorus concentration of the rice plant during different stages of growth *viz.*, tillering, flowering and harvest of rice ranged from 0.192 % to 0.207% (Table 4). Statistical analysis of data and comparison of treatment mean revealed significant influence of amendments on phosphorus content of plants during all the three growth stages. Phosphorus contents were highest during flowering and lowest at harvest. The average P content of plants pooled over three growth stages showed significant influence of amendment treatments. The plant P content was highest in chemical fertilizer treated plots (T_6) obviously due to higher availability of inorganic P content of soil. The plant P content under glyricidia application was comparable to that under chemical fertilizer treatment. All other plots had similar plant P content. Phosphorus content of plant at different stages of growth were significantly correlated with available P (AP) at tillering (r=0.70**), flowering (r=0.52**) and harvesting (r=0.51*) (Table 3). Similarly P concentration of rice leaves during flowering and maturity also were significantly influenced.

Table 4: Effect of amendments on the total P content of rice plants at different growth stages

Treatments	Total P (%) content in rice plant			
	Growth period			
	Tillering	**Flowering**	**Maturity**	**Mean**
Control	0.18c	0.229a	0.165b	**0.19^{B}**
Rice straw	0.19c	0.230a	0.157b	**0.19^{B}**
Gliricidia	0.18c	0.236a	0.182a	**0.20^{AB}**
FYM	0.20b	0.227a	0.161b	**0.20^{B}**
Vermi compost	0.19c	0.234a	0.157b	**0.19^{B}**
Chemical fertilizer	0.22a	0.236a	0.165b	**0.21^{A}**
Mean	**0.19^{Q}**	**0.23^{P}**	**0.17^{R}**	
SEm (±)	**0.004**	**0.003**	**0.003**	
LSD(0.05)	**0.012**	**0.009**	**0.009**	

Note: In a column values with similar alphabet are not significantly different through DMRT (P=0.05)

Grain yield and straw yield

Grain yield and straw yield recorded after harvest of rice under different treatments ranged from 2.05 to 4.32 t ha^{-1} and 2.25 to 4.65 t ha^{-1} (Table 5). Statistical analysis of data and comparison of treatment means revealed significant influence of amendment application on grain yield and straw yield. While control treatment (T_1) effectuated the lowest, application of chemical fertilizer alone (T_6) produced the highest.

Table 5: Effect of amendments on the grain and straw yield of rice

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Control	2.05^e	2.25^{f*}
Rice straw	3.17^d	3.31^e
Gliricidia	3.68^c	3.98^d
FYM	3.97^b	4.12^c
Vermi compost	4.24^a	4.5^b
Chemical fertilizer	4.32^a	4.65^a
Mean	**3.57**	**3.8**
SEm (±)	**0.07**	**0.05**
LSD(0.05)	**0.20**	**0.15**

Note:In a column values with similar alphabet are not significantly different according to DMRT (P=0.05)

The grain yield under vermicompost treatment (T_5) was comparable to the grain yield in T_6 treatment. Grain yield and straw yield under different treatments followed the order: T_6=T_5>T_4>T3>T_2>T_1.

Regression of grain yield with available phosphorus

Simple regression analysis of grain yield with available phosphorus during the three growth stages of rice and plant parameters were done (Table 6). Available P content of soil had strong influence on grain yield (R=0.95**). Out of three growth stages studied, available P during harvest seemed to have significant influence on grain yield. About 90% (R^2=0.90**) of the variability in grain yield could be explained by this.

Table 6: Regression of grain yield with available P in the rhizosphere at different growth stages of rice

Variables	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	**SE**	**Beta**		
(Constant)	-0.79	0.40		-1.95	0.07
AV_P (Tillering)	0.03	0.05	0.10	0.67	0.51
AV_P (Flowering)	0.09	0.06	0.23	1.37	0.19
AV_P (Maturity)	0.19	0.05	0.65	3.70	**0.00**
	R	**R^2**	**Adj. R^2**	**SE**	
	0.95	**0.90**	**0.89**	**0.27**	

Note: Dependent Variable: Grain yield, Predictors: (Constant), Available P (AV_P) during tillering, flowering and maturity

Application of amendments significantly influenced the available phosphorus and yield of rice in comparison with control. Application of chemical fertilizer or vermicompost effectuated highest amount of available phosphorus. These two treatments eventually also resulted in highest yield of rice. Among the organic amendments in general, rice straw was the inferior most. Simple regression analysis of grain yield with available phosphorus during the three growth stages of rice and plant parameters revealed that available P during harvest seemed to have significant influence on grain yield. About 90% (R^2=0.90**) of the variability in grain yield could be explained by this.

REFERENCES

Bohn, H. L., McNeal, B. L. and O'Connor, G. A. 1979. *Soil Chemistry.* Wiley, New York.

Bouyoucos, G.J. 1962. Hydrometer method for making particle size analysis at soils. *Agron. J.*, **54**: 464-65.

Bray, R.H. and Kurtz, L.T. *1945.* Determination of total organic and available forms of phosphorus in soil. *Soil Sci.*, **59**: 36-46.

Fairhust, T., Lefroy, R.,Mutert, E. and Batjes, N. 1999.The importance, distribution and causes of phosphorus deficiency as a constraint to crop production in the tropics. *Agroforestry Forum*, **9:**2-8.

Gerke, J. 1992.Orthophosphate and organic phosphate in the soil solution of four sandy soils in relation to pH: evidence for humic-Fe (Al) phosphate complexs. *Soil Sci and Pl Ana*., **23:** 601- 12.

Gomez, K. A. and Gomez, A. A. 1984. *Statistical procedure for Agricultural Research.* 2nd Edn., John Willey and Sons, New York.

Hegde, D.M. and Dwivedi, B.S. 1993.Integrated nutrient management for dry land agriculture. *Fert. News.*, **39**:19-26.

Hue, N. V.; Craddock, G. R. and Adams, F. 1986**.**Effect of organic acids on aluminium toxicity in subsoils. *Soil Sci. Soc. America J.*, **50:**28-34.

Jackson, M.L. 1973. *Soil Chemical Analysis.* Prentice Hall of India Pvt. Ltd., New Delhi, pp. 498.

Katznelson, H., Lochhead, A.R. and Timinin, M.L. 1948.Soil microorganisms and the rhizosphere. *Bot. Rev.*, **14**: 543-87.

Laxminarayana, K. and Patiram. 2006. Effect of integrated use of inorganic, biological and organic manures on rice productivity and soil fertility in Ultisols of Mizoram. *J. Indian Soc. Soil Sci.*, **54**: 213-20.

Magid, J., Tiessen, H. and Condron, L. M. 1996. Dynamics of organic phosphorus in soils under natural and agricultural ecosystems**.** *In. Humic substances in Terrestrial*

Ecosystems **(**Ed. Piccolo, H.), Elsevier, Amsterdam, pp. 429-66.

Maharajan, K. K., Singh, R., Sharma, V. K., Acharya, C. L., Deo, B.S., Goyal, N. K. and Masand, S. 1997. Integrated nutrient management in maize (*Zea mays*)-wheat (*Triticum aestivum*) sequence under rainfed condition in Himachal Pradesh. *Indian J. Agril. Sci.*, **67:** 560-63.

Nambier, K.K.M. and Abrol, I.P. 1989. Long term fertilizer experiments in India:an overview. *Fert News.*, **34**: 11-26.

Nziguheba, G. and Bů̂nemann, E. 2005. Organic phosphorus dynamics in tropical agroecosystems, *In. Organic Phosphorus in the Environment* (Eds. Turner, B. L., Frossard, E. and Baldwin, D. S.), CAB International, Wallingford, UK, 243-68.

Patrick, W.H. Jr., Mikkelsen, D.S. and Wells, B.R. 1985. Plant nutrient behavior in flooded soil. *In. Fertilizer Use and Technology*, 3d Edn., Soil Sci. Soc. America, Madison, Wisconsin, pp. 197-28.

Ponnamperuma, F. N. 1972. The chemistry of submerged soils. *Adv. Agron.*, **24**:29-96.

Ponnamperuma, F. N. 1985. Chemical kinetics of wetland rice soils relative to soil fertility. *In. Wetland Soils: Characterization, Classification and Utilization*, Int. Nat. Res. Inst., Los Banos, Laguna, Philippines, pp. 71-89.

Sanyal, S. K. and De Datta, S. K. 1991.Chemistry of phosphorus transformation in soil. *Adv. Soil Sci.*,**16:**2-120.

Sakhen, S., Nabachandra and Anando, N. 2011. Influence of different sources of phosphorus and phosphate solubilising bacteria on productivity of rainfed rice (Oryza sativa L.). *J. Crop and Weed*, **7**:41-43.

Schollenberger, C. J. and Simon, R. H. 1945. Determination of exchange capacity and exchangeable bases in soil by ammonium acetate method. *Soil Sci*., **59**: 13-24.

Shand, C. A., Sim, A., Sellars, S.and Ord, B. G.1997. Uptake and transport of phosphorus by Agrostis capillaries seedlings from rapidly hydrolysedorganic sources extracted from ^{32}P – labeled bacterial cultures. *Pl. Soil.*, **190:** 163-67.

Singh, V., Dhillon, N. and Brar, B. 2006.Effect of incorporation of crop residues and organic manures on adsorption/Desorption and bio-availability of phosphate. *Nutrient Cycling in Agroeco.*,**76**: 95-108.

Subehia, S.K., Verma, S. and Sharma, S.P. 2005. Effect of longterm use of chemical fertilizers with and without organics on forms of soil acidity, phosphorus adsorption and crop yields in an acid soil. *J. Indian Soc. Soil Sci.,* **53**: 308-14.

Tiessen, H. and Shang, C. 1998. Organic matter turnover in tropical land use systems. *In. Carbon and Nutrient Dynamics in Natural and Agricultural Tropical Ecosystems* (Eds. Bergstrom, L. and Krichmann, H.), CAB International, pp. 1-14.

Tirol-Padre, A., Ladha, J.K., Regmi, A.P., Bhandari, A.L. and Inubushi, K. 2007. Organic amendments affect soil parameters in two long term rice-wheat experiments. *Soil Sci. Soc. America J.* **71**: 442-52.

Tolanur, S.T. and Badanur, V.P. 2003. Effect of integrated use of organic manure, green manure and fertilizer nitrogen on sustaining productivity of rabi sorghum-chickpea system and fertility of a vertisol. *J. Indian Soc. Soil Sci.,* **51**: 41-44.

Varalakshmi, L.R., Srinivasmurthy, C.A., Bhaskar, S. 2005. Effect of integrated use of organic manures and inorganic fertilizers on organic carbon, available N, P and K in sustaining productivity of groundnut-finger millet cropping system. *J. Indian Soc. Soil Sci.,* **53**: 315-18.

Vats, M. R., Sehgal, D. K. and Mehta, D.K. 2001.Integrated effect of organic and inorganic manuring on yield sustainability in long-term fertilizer experiments. *Indian J. Agri. Res.,* **35**: 19-24.

Walkley, A. J. and Black, I. A. 1934. Estimation of soil organic carbon by the chromic acid titration method. *Soil Sci.,* **37:** 29-38.

Zibilske, L. M., Bradford, J. M. and Smart, J. R. 2002. Conservation tillage induce changes in organic carbon, total nitrogen an available phosphorus in a semi-arid alkaline subtropical soil. *Soil Till. Res.*, **66:** 153-63.